Proceedings of the 14th Biennial Coastal Zone Conference
New Orleans, Louisiana
July 17 to 21, 2005

NONTOXIC ANTIFOULING? DEMONSTRATING A SOLUTION TO COPPER BOAT BOTTOM PAINT POLLUTION!

Leigh Taylor Johnson, University of California Sea Grant Extension Program
Jamie Anne Gonzalez, University of California Sea Grant Extension Program

Keywords: antifouling, nontoxic bottom paints, water quality, clean boating

BACKGROUND

Every sailor knows that fouling organisms love to hitch a ride on the hulls of ships. Today, cuprous oxide-containing antifouling paints are the weapon of choice in the search for vessel fuel efficiency and speed. However, copper levels are rising in crowded boat basins with poor circulation.

Copper-based boat bottom paints are legally registered pesticides (CDPR 2004) that are likely to face new restrictions. For example, Total Maximum Daily Load (TMDL) regulatory studies have been completed in Shelter Island Yacht Basin of San Diego Bay and in Newport Bay (CRWQCB, SDR 2003; USEPA 2002). A TMDL study is underway in Marina Del Rey. Oceanside Harbor and various parts of San Diego Bay have elevated levels of dissolved copper (CSWRCB 2002 Monitoring List Region 9 approved by USEPA 2003).

The federal and state standard for total dissolved copper in marine waters is 3.1 parts per billion (ppb); the USEPA is considering changing it to 1.9 ppb (USEPA 2004). TMDL studies found copper levels as high as 8.0 ppb in San Diego Bay and as high as 29.0 ppb in Newport Bay (CRWQCB, SDR 2003; USEPA 2002). Another study found that up to 90% of dissolved copper in the boat basins comes from bottom paints (Schiff et al. 2003). The Regional Water Quality Control Board, San Diego region, adopted the Basin Plan Amendment to incorporate the TMDL for dissolved copper in Shelter Island Yacht Basin in February 2005. It includes restrictions on copper-based bottom paints.

Copper-based bottom paints have been banned for pleasure craft on the east coast of Sweden and are restricted on the west coast of Sweden and in Denmark depending on cuprous oxide leach rates and vessel size. Copper-based antifouling paints have been banned in the Netherlands for recreational boats since 1999. (Swedish Chemicals Inspectorate 2004; Ministry of the Environment Danish Environmental Protection Agency 2003; The Netherlands Ministry of Housing, Spatial Planning and the Environment 2004; College Toelating Bestrijdingsmiddelen 2004)

When the dissolved copper level exceeds the standard, it is harmful to marine life such as mussels, oysters, scallops, sea urchins and crustaceans. It also changes the types of phytoplankton that are able to thrive in boat basins. (Calabrese et al.1984; Coglianese & Martin 1981; Gould et al. 1988; Katz 1998; Krett Lane 1980; Krishnakumar et al. 1990;

Lee & Xu 1984; Lussier et al.1985; MacDonald 1988; Martin et al. 1981; Redpath 1985; Redpath & Davenport 1988; Stromgren & Nielsen 1991; VanderWeele 1996)

Alternatives are needed to control fouling growth while reducing bottom paint pollution. Nontoxic antifouling strategies combine a nontoxic boat bottom coating with a companion strategy. Examples of companion strategies include: frequently cleaning the coating, storing the boat out of water, and surrounding the boat with a slip liner and adding freshwater to discourage marine fouling growth.

Nontoxic coatings are more expensive to apply and must be cleaned more often than copper-based paints. In San Diego Bay, nontoxic coatings are cleaned approximately twice a month. In addition, some nontoxic products have special application needs. Since most nontoxic coatings can not be applied over copper-based paints, it would be most economically beneficial to switch to a nontoxic paint when the boat is ready to be stripped. A survey of 200 randomly selected boaters in San Diego Bay revealed that most boaters strip old copper paint approximately every 15 years. In deciding whether to switch to a nontoxic coating, boat owners should consider whether a nontoxic coating is required where the boat is kept, the cost of switching to and maintaining a nontoxic coating, and the environmental benefits of reducing copper pollution.

METHODS

To help boat owners make decisions about nontoxic antifouling strategies, the University of California - Cooperative Extension- Sea Grant Extension Program conducted a field demonstration of three nontoxic boat bottom coatings in 2002-2003. The project was funded in part by the US EPA and the California State Water Resources Control Board 319(h) Program. The field demonstration was in cooperation with six vessel owners, a boat repair yard and three underwater hull cleaning companies. The nontoxic coatings included an epoxy coating, a ceramic-epoxy coating, and a silicone-rubber coating.

The two-part epoxy coating, Aquaply M,® was placed on a powerboat for the demonstration and it was monitored on a sailboat that had received it in January of 1999. We received hull cleaning data on the sailboat for July, 1999 through September, 2003 which provided an opportunity to assess longer-term performance of Aquaply M.® The ceramic-epoxy coating, CeRam-Kote 54,® was placed on a sailboat and a diesel-electric launch. A newer formulation, CeRam-Kote Marine,® was placed on the sailboat partway through the project. The silicone-rubber coating, Miracle Cover,® was replaced by an updated formulation, Miracle Cover Marine,® partway through the demonstration period.

Each time the boats were cleaned, divers reported on fouling growth, coating condition, aggressiveness of cleaning tool and effort, cleaning time and interval since the last cleaning. The first four factors were rated on a five-point scale developed in cooperation with the California Professional Divers Association with 1 as the lowest level of fouling, best coating condition, least aggressive cleaning tool, and least diver effort.

On average the epoxy and ceramic-epoxy coatings were cleaned every 15 to 18 days while the silicone-rubber coatings were cleaned on average every 7 to 12 days (cleaning schedules were set by the boat owners in consultation with their hull cleaning companies). Daily water temperatures and angle of sunlight were also collected. We worked with Dr. Neil Willits of the UC Davis Statistical Laboratory to examine the relationship of these variables within the data.

RESULTS

Overall, water temperature and time since the last cleaning were primary predictors of fouling growth. The Best Management Practices (BMPs) of using a gentler tool and cleaning frequently were the best practices for extending coating life and compensating for higher application and cleaning costs. Cleaning more frequently prevents fouling growth from accumulating to high levels. In turn, this allows divers to use less aggressive cleaning tools, spend less time cleaning, and exert less effort. Frequent cleaning may thus be expected to extend the life of the coating, reduce the cost of each cleaning and reduce wear and tear on hull cleaners. This is especially important when water is warmer. The fouling growth means were the highest for the boats with the ceramic-epoxy coating (in the range of levels 3 to 4) and the lowest for the boats with the silicone-rubber coating (in the level 2 range), reflecting that the silicone-rubber coating was cleaned more often.

We found that using a power cleaning tool also allows divers to use a less aggressive tool and exert less effort. Visual inspection found that a 5-year old, epoxy coating which had been cleaned with powered tools had become smoother than when it was applied.

The epoxy and ceramic-epoxy coatings have the potential to last many more years than copper-based coatings and the silicone-rubber coating that was used in our demonstration. The silicone-rubber coating was preferred by boat owners who liked to race and were willing to invest in very frequent cleaning and annual replacement. The epoxy and ceramic-epoxy coatings appear to be a good choice for boat owners who want a nontoxic coating that may last long enough to compensate for costs incurred in more frequent cleaning and converting from a copper-based coating. The epoxy coating that was 5 years old by the end of the demonstration project was expected to last at least 2 more years. The ceramic-epoxy appeared likely to have similar durability while the silicone-rubber coating had to be replaced annually. These products may perform differently in other areas.

DISCUSSION

Nontoxic antifouling strategies are a viable alternative to copper-based boat bottom paints. In selecting a nontoxic coating, boat owners should consider how they will use the boat and the availability, longevity and costs of various nontoxic coatings. They will need to ensure that the hull cleaner uses BMPs that may extend the life of the coating, such as cleaning frequently and using the gentlest tool that is appropriate. Hull cleaning companies will need to learn and use BMPs that are suitable for the coating, the geographic area, and how the boat is used and stored. Boat repair yards will need to acquire special equipment and learn to apply nontoxic coatings.

Although our demonstration included a small number of boats, the results suggest that nontoxic coatings can be a good choice for some boat owners. The epoxy and ceramic-epoxy coatings may serve other boat owners as durable, barrier coats. New coatings that are still in development may prove to be suitable for those who wish or are required to use environmentally-friendly alternatives to copper-based antifouling paints.

The UC Sea Grant Extension Program has published two booklets: "Staying Afloat with Nontoxic Antifouling Strategies for Boats" summarizes the results and conclusions of the nontoxic bottom coatings field demonstration from 2002 to 2003; "Making Dollars and Sense of Nontoxic Antifouling Strategies for Boats" is based on a study mandated by Senate Bill 315 on the economics of switching to nontoxic boat bottom coatings in San Diego. These booklets and more information can be found at http://seagrant.ucdavis.edu

LITERATURE CITED

Calabrese, A., J.R. MacInnes, D.A. Nelson, R.A. Greig and P. P. Yevich. 1984. Effects of Long-term Exposure to Silver or Copper on Growth, Bioaccumulation and Histopathology in the Blue Mussel *Mytilus edulis*. *Marine Environmental Research.* 11:253-274.

California Department of Pesticide Regulation. 2004. California Code of Regulations (Title 3. Food and Agriculture) Division 6. Pesticides and Pest Control. http://www.cdpr.ca.gov/docs/inhouse/calcode/020101.html

California Regional Water Quality Control Board, San Diego Region. 2003. Total Maximum Daily Load for Dissolved Copper in Shelter Island Yacht Basin, San Diego Bay, Public Review Draft. http://www.waterboards.ca.gov/sandiego/tmdls/shelter%20island.html

California State Water Resources Control Board. 2003. The Section 303(d) List of Water Quality Limited Segments. 2002 Monitoring List: Region 9 approved by USEPA 2003: (Oceanside Harbor and in San Diego Bay: America's Cup Harbor, Harbor Island, Laurel Street, Marriott Marina, North Island Aircraft Platform) http://www.swrcb.ca.gov/tmdl/docs/2002_mon_list_020403.pdf

Coglianese, M. P., and M. Martin. 1981. Individual and Interactive Effects of Environmental Stress on the Embryonic Development of the Pacific Oyster, *Crassostrea gigas*. I. The Toxicity of Copper and Silver. *Marine Environmental Research*, 5:13-27.

College Toelating Bestrijdingsmiddelen. 2004. www.ctb-wageningen.nl

Gould, E., R.J. Thompson, L.J. Buckley, D. Rusanowsky, and G.R. Sennefelder. 1988. Uptake and Effect of Copper and Cadmium on the Gonad of the Scallop *P. magellanicus*: Concurrent Metal Exposure. *Marine Biology*, 97:217-223.

Johnson, L.T. and J.A. Gonzalez. 2004. Staying Afloat with Nontoxic Antifouling Strategies for Boats. Californian Sea Grant College Program Technical Report No. T-054.

Johnson, L.T. and J.A. Miller. 2003. Making Dollars and Sense of Nontoxic Antifouling Strategies for Boats. Californian Sea Grant College Program Technical Report No. T-052.

Katz, C. 1998. Seawater Polynuclear Aromatic Hydrocarbons and Copper in San Diego Bay. Technical Report 1768. Space and Naval Systems Center. San Diego, CA.

Krett Lane, S. M. 1980. Productivity and Diversity of Phytoplankton in Relation to Copper in San Diego Bay. Technical Report 533. Naval Oceans Systems Center.

Krishnakumar, P. K., P.K. Asokan, and V. K. Pillai. 1990. (Abstract) Physiological and Cellular-Responses to Copper and Mercury in the Green Mussel *Perna-Viridis* (Linnaeus). *Aquatic Toxicology*, 18(3):163-173.

Lee, H. H. and C. H. Xu. 1984. Effects of Metals on Sea Urchin Development: A Rapid Bioassay. *Marine Pollution Bulletin*, 15:18-21.

Lussier, S. M., J. H. Gentile, and J. Walker. 1985. Acute and Chronic Effects of Heavy Metals and Cyanide on *Mysidopsis bahia* (Crustacea: Mysidacea). *Aquatic Toxicology*, 7:25-35.

MacDonald J.M., J.D. Shields, and R. K. Zimmer-Faust. 1988. Acute Toxicities of Eleven Metals to Early Life-history Stages of the Yellow Crab *Cancer anthonyi. Marine Biology*, 98:201-207.

Martin, M., K.E. Osborn, P. Billig, and N. Glickstein. 1981. Toxicities of Ten Metals to *Crassostrea gigas* and *Mytilus edulis* Embryos and *Cancer magister* Larvae. *Marine Pollution Bulletin*, 12:305-308.

Ministry of the Environment Danish Environmental Protection Agency. September 2003 http://www.mst.dk/activi/01060000.htm

The Netherlands Ministry of Housing, Spatial Planning and the Environment. 2004. http://www2.vrom.nl/pagina.html?id=4802

Redpath, K. J. and J. Davenport. 1988. The Effect of Copper, Zinc, and Cadmium in the Pumping Rate of *Mytilus edulis* L. *Aquatic Toxicology*, 13:217-226.

Redpath, K. J. 1985. Growth Inhibition and Recovery in Mussels (*Mytilus edulis*) Exposed to Low Copper Concentrations. *Journal of the Marine Biological Association of the United Kingdom*, 65(2):421-31.

Schiff, K., D. Diehl and A. Valkirs. 2003. Copper Emissions from Antifouling Paint on Recreational Vessels. SCCWRP Technical Report #405. Southern California Coastal Water Research Project, Westminster, CA.

Stromgren, T. and V. Nielsen. 1991. Spawning Frequency, Growth, and Mortality of *Mytilus edulis* Larvae, Exposed to Copper and Diesel Oil. *Aquatic Toxicology*, 21:171-180.

Swedish Chemicals Inspectorate. 2004. http://www.kemi.se/lang/english/index.html

US Environmental Protection Agency. 2004. Draft Updated Water Quality Criteria for Copper. http://www.epa.gov/waterscience/criteria/copper/draftupdatefs.htm

US Environmental Protection Agency. 2002. Total Maximum Daily Loads for Toxic Pollutants: San Diego Creek and Newport Bay, CA. U.S. EPA Region 9, San Francisco, CA. http://www.epa.gov/Region9/water/tmdl/nbay/summary0602.pdf

VanderWeele, D.A. 1996. The Effects of Copper Pollution on the Bivalve, *M. edulis* and the Amphipod, *G. japonica* in the Shelter Island Yacht Basin, San Diego Bay, California. M.S. Thesis. San Diego State University, San Diego, CA.

Leigh Taylor Johnson and Jamie Anne Gonzalez
University of California Sea Grant Extension Program
County of San Diego MS O-18, 5555 Overland Avenue, Suite 4101
San Diego, CA 92123
Phone: (858) 694-2852, (858) 694-3414
E-mail: ltjohnson@ucdavis.edu, jagonzalez@ucdavis.edu